Protective ability of electrodeposited and electroless Ni–P alloy coatings on mild steel in saline media

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Nickel phosphorus (Ni–P) alloys are of great interest because of their useful properties such as anticorrosive protection, wear resistance, high hardness, low friction coefficient, paramagnetic characteristics, catalytic activity in hydrogen evaluation reaction. Although Ni–P coatings have been intensively studied, their protective properties are still not completely understood [1, 2]. In particular, no comparison of protective ability of Ni–P alloys produced by different methods can be found in literature. Since the commonly used methods for Ni–P coatings production are electrodeposition and electroless deposition, the present work was focused on comparing the protective properties of electroless and electrodeposited Ni–P coatings. The phosphorus content in Ni–P coatings is known to affect strongly their structure and anticorrosion properties. Therefore we prepared the electrodeposited Ni–P coatings with the phosphorus content 5.5, 10.0 and 21.5 at. %, which had microcrystalline, amorphous-crystalline and amorphous structure respectively. Since in the case of electroless deposition the P content in the coatings cannot be varied by changing the parameters of deposition process, we prepared electroless Ni–P coatings containing only 10 at. % of phosphorus which had amorphous-crystalline structure. The thickness of both kinds of the coatings was about 20 μm.

A systematic study of the effect of phosphorus content and the origin of Ni–P coatings on their protective ability on a mild steel substrate in saline media (3.5 % NaCl) was performed. Impedance spectroscopy was used as a powerful method for diagnostics of corrosion processes because of its high sensitivity to surface state in aqueous solutions. Immersion corrosion test of the coatings in saline solution was conducted for 1000 hours (about 40 days). During this period impedance spectra of the samples were periodically recorded under open circuit conditions, and then fitted with Nova software using corresponding equivalent circuits.

The research revealed a great difference in protective ability of the electrodeposited Ni–P coatings with different phosphorus content. Calculated charge transfer resistance (R_{ct}) of the electrodeposited crystalline Ni–P samples strongly fluctuated in the range of 10-40 kOhm·cm^2 during the first 10 days and then was stabilized at 10–15 kOhm·cm^2. Then after 680 hours of testing the R_{ct} began to rise up to 40 kOhm·cm^2. This behavior can be due to the penetration of aggressive chloride ions though pores and microcracks of the coating to steal substrate. Unlike crystalline samples, the R_{ct} of amorphous-crystalline and amorphous coatings increased rapidly in early hours of testing from 15 up to 200 kOhm·cm^2, indicating the formation of a thin protective film on the coatings surface. Then the R_{ct} growth rate decelerated, and after 1000 hours of testing the R_{ct} of electrodeposited Ni–P (10 at. % P) was about 300 kOhm·cm^2. In comparison with the electrodeposited Ni–P coatings, the electroless Ni–P coating containing 10 at. % P demonstrated very low values of the R_{ct} (about 7–8 kOhm·cm^2) during the whole period of testing, evidencing active corrosion processes of the samples.

Thus the results obtained show that only amorphous-crystalline and amorphous electrodeposited Ni–P coatings can provide effective protection against corrosion in saline media. Electroless Ni–P coatings with amorphous-crystalline structure do not protect mild steel under these conditions due to rheir active dissolution.

References

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